UDC 666.1.053.562:621.867.6:528.5

REFINEMENT OF GEODETIC MEASUREMENTS IN CONSTRUCTION AND OPERATION OF FLOAT-GLASS LINES WITH A CONTINUOUS PRODUCTION CYCLE

V. I. Novikov[1] and A. B. Rassada[1]

Translated from Steklo i Keramika, No. 7, pp. 8 – 11, July, 2005.

The authors justify the need to use geodetic measurements to detect deformation processes on rotating surfaces of roller conveyors on industrial sheet-glass production lines. The geodetic instruments used for this purpose are described and their principle of action is analyzed.

No building project today can be implemented without corresponding geodetic support. The requirements on the precision of geodetic services are regulated by state standards and sanitary norms and regulations.

Geodetic support includes layout works and periodic monitoring of structural deformations in buildings, service lines, and machinery during installation and service. The mean quadratic error in geodetic measurements can be accepted as 20% of the admissible deviation specified in the Construction Norms and Specifications. Hence one can estimate the required accuracy of geodetic measurements. It should be noted that contemporary engineering involves construction of large industrial facilities that require a high precision of geometrical relations of all units in the technological lines. Furthermore, such industrial complex should satisfy the condition of time stability of the deformation properties of its structural and technological elements. This is especially important for industrial conveyors in fine-technology lines.

A modern facility is an integrated complex, where the final result depends on precise operation of all technological units, although their operating regimes may be different. Examples of such production facilities are sheet glass production lines in Saratov, which integrate several technological units continuously operating under different service conditions.

Different service condition of machines impose certain requirements on geodetic servicing of the production complex. The conditions of geodetic measurements in the course of installation are roughly the same for the whole complex, but later on, when each machinery item requires deformation stability control, the traditional methods of geodetic measurements in some cases do not provide necessary accuracy. Therefore, one needs new methods for performing geodetic work in particular conditions. Furthermore, additional problems arise in operation, which do no exist in the installation period, such as protecting instruments from unfavorable ambient conditions, vibration fields, and machinery wear.

The results of geodetic measurements are relevant to solving the above problems. Thus, the Saratov sheet glass production line has four main machinery components: the glass-melting furnace, the melt tank, the annealing furnace, and the roller conveyor. They operate in different conditions, which differ significantly from the installation conditions; the temperature in the glass-melting furnace, the melt tank, and the annealing furnace increases significantly in operation, furthermore, intense vibration fields arise in the annealing furnace and on the roller conveyor. The monitoring of the annealing furnace and the roller conveyor to detect deformation processes requires geodetic measurements on rotating surfaces.

In this context, the aim of the authors was to develop tools and methods for geodetic measurements to be used for rotating rollers of the roller conveyor and the annealing furnace and also under the conditions of poor visibility and intense vibration in the production zone.

In the first case a special leveling rod was designed allowing for leveling the conveyor rollers during their rotation and in the second case we developed a laser sighting device combined with another leveling rod to compensate for poor lighting and intense vibration.

Rods for precision leveling of rotating surfaces. The use of traditional geodetic measurement methods in the course of installation, adjustment, and periodic monitoring of certain segments of the conveyor lines containing rotating surfaces, for instance roller conveyors, is problematic. In fact, the traditional method of precision leveling ensures the required precision of installation works, but these methods

[1] Saratov State Technical University, Saratov, Russia.

0361-7610/05/0708-0202

become inapplicable during operation. The conveyor, as a rule, has a continuous production cycle, therefore, stopping a technological unit even for a short time is impossible. This calls for new measuring methods and sometimes new measuring instruments. In our case we propose a modified leveling rod for precision leveling of conveyors rolls during their rotation. The modification consists in designing a special rod heel that would allow for precision leveling of the rollers both in the stationary mode and in rotation. For this purposed the leveling rod was placed on a platform enabling its rotation around the vertical axis (Fig. 1).

Leveling using this rod was performed as follows. The telescopic systems were detached and the rod was placed atop the roller for the support and fixing bearings to contact the roller surface. This preparatory work was carried out before leveling for the purpose of taking into account the roller diameters at the given production line. Having fixed this position with the telescopic system clamps, the rod was turned facing the observer. After that the reading procedure was performed, which is prescribed by precision leveling requirements.

The advantages of the specified rod were tested during the repair of the sheet glass production line at the Saratovstroisteklo Company.

Experimental studies were performed in two stages: during the installation of the conveyor rollers and during the operation of the conveyor. This made it possible to evaluate more objectively the proposed rod design in leveling the rotating roller surfaces. The validity of the estimate was determined by means of leveling rollers in first statically and then in dynamics.

In the first case, the measurement conditions fully satisfied the requirements on precision leveling. Altogether 103 rollers were leveled during the installation of the conveyor, each on the left and the right side. Leveling was carried out using a standard rod with 5-mm graduation and the rod with the modified heel (Fig. 1).

Accepting the results of the first leveling as true values, we estimated the results of leveling with a modified rod. In general the results were satisfactory: the mean quadratic error in determining the roller elevation was ± 0.3 mm. True, we excluded gross errors from the error series, since our analysis indicated that they were caused by inaccurate roller manufacture and their unsatisfactory asbestos coatings: the roller diameters in some cases differed nearly by the value of leveling accuracy. This affected the mounting of the leveling rod on the roller top: sometimes when the lateral fixing bearings were fixed, the support bearing did not touch the roller surface, in other cases the end of the rod was unsteady and the support bearing kept slipping off the top to one or the other side, which changed the readings. The values of such variation was relatively low, however, it existed. This circumstance suggested the idea of replacing the single support bearing by two bearings and leaving only fixing spring clamps in the lateral telescopic systems. In such a case the

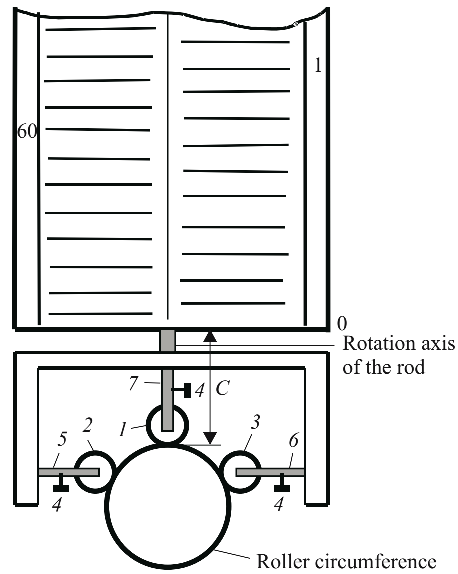

Fig. 1. Diagram of modified leveling rod: *1*) support bearing; *2*, *3*) fixing bearings; *4*) clamps of telescopic systems; *5*, *6*) telescopic systems with spring compression of the fixing bearings; *7*) telescopic system of the support bearing; *C*) difference between the existent rod heel and the modified rod heel.

bearings would be positioned on both sides of the roller top and their constancy would be maintained. This modification was not studied by the authors, since it required making a new heel.

After obtaining positive results in leveling with the modified rod, experiments were continued on rotating rollers, where the standard rod could not be applied. The modified rod allowed for leveling, although certain difficulties were observed.

These difficulties originated on the operating line due to inaccurate manufacture of rollers and their asbestos coatings. It could be expected that roller vibration is inevitable, but the true situation was discovered in dynamics, i.e., in the course of the roller rotation. We had to register the maximum and minimal indications and the final value was taken as the mean of the obtained values. Despite taking this measure, the leveling precision was lower than on stationary rollers: the error increased 2 – 3 times. It should be noted that vibration of rollers is the main source of error in leveling rotating surfaces. These difficulties increase in finding mean indications on the sites of vibration fields, where vibration directions are added to the roller vibrations. Furthermore, a certain difficulty arises in mounting the rod to a vertical position on a rotating surface, therefore, the rod should be equipped with a circular level, which will eliminate the error caused by the deviation of the rod from the vertical direction.

The vibrations of the rollers decrease the accuracy of measurements, whereas the presence of general vibration occasionally prevented getting any results due to the rod image in the telescope becoming blurred. This suggested that the

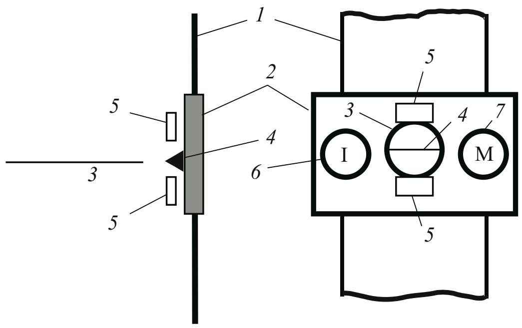

Fig. 2. Scheme of leveling rod and laser sighting device.

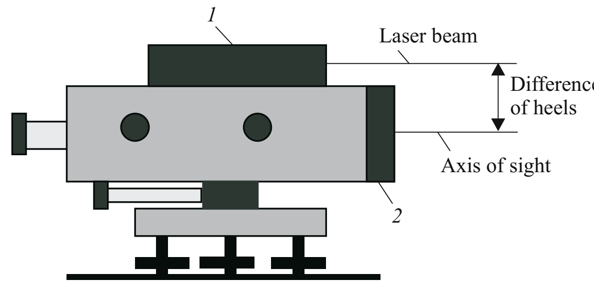

Fig. 3. Scheme of combination of laser and leveler: *1*) laser sight; *2*) leveler N05.

rod should be read directly. To do that, the crosshair projection should be visible on the rod, which is possible only when a laser beam is used as the sighting axis.

It should be noted that the purpose of our experiments was not obtaining high-precision leveling results, although that was taken into account as well, but to verify the possibility of using the modified rod design in unfavorable conditions to obtain results that satisfy this leveling principle. Since the above-mentioned sources of error actually affect the accuracy of results in any leveling method and have no direct relation to the described experiments, in fact we studied methods for applying modified rods. It was found that leveling rotating rollers of the roller conveyor using the described rod does not complicate the reading procedure compared to leveling static rollers using standard rods; moreover, the leveling results meet the requirements and tolerances imposed on this type of measurement. The cost of modifying the rod heel is minimal.

Rods for precision leveling using laser sight. It is known that high-precision geometrical leveling in real industrial conditions, especially in basements, is hampered by ambient conditions: poor lighting, presence of additional pipelines and air conduits, intense noises, high temperature, high dust content and, which is very significant, intense vibration fields generated by working machines.

In this context we were paying attention to two problems: visibility and vibration. The first problem was solved by directly reading the points of the sight projection on the rod graduation scale. The second problem was solved together with the first one, since direct reading of the rod virtually eliminates the effect of image blurring in the telescope.

Vibrations in the course of geometrical leveling causes resonance vibrations of pendulum tilt, compensators, oscillations of the sighting line and the level bubble, blurring of the rod image.

Experiments demonstrated that N05 and N3 levels are the steadiest. However, even using the above levels under a vibration frequency of 50 Hz and an amplitude of 20 – 40 μm, the "vision" error is 20 – 45% higher than under normal conditions. Under higher amplitudes the image blurring is so significant that it is impossible to take readings of the rod. The sighting accuracy under vibration is several times lower than under normal leveling conditions. Therefore, the purpose of the authors was to read the rod directly, which required using a laser sight for precision leveling of settling marks in the structural supports of the conveyor. The laser sight solves the poor visibility problem as well. However, a laser sighting device in itself cannot solve the problem, since its is not clear how one can read the rod with a projected laser spot which is significantly larger than the crosshair size. To solve this problem, we propose a leveling rod equipped with a laser sight (Fig. 2), i.e., a rod *1* with a moving frame *2*, on which the laser beam receiver *3* is installed: it can be a sliding bisector (similar to a beam compass) or an optical wedge *4* (beam splitter) with light-emitting diodes *5*.

The use of an optical beam splitter with LED raises the accuracy of reading the rod by an order of magnitude. As the frame moves along the rod until the laser sight beam hits it, the beam splitter receives the light spot on an optical wedge fixing the split fluxes to the respective light-emitting diodes *5*. The values of the light fluxes is registered on indicator *6*. If the frame is moved manually, the difference between the LED readings on the indicator is eliminated by moving the frame with the micrometric screw. In the case of automated shift of the frame the difference in the LED readings is eliminated by microelectric motor *7*. Even under a very large vibration amplitude the optoelectron method for localizing the center of the laser light spot provides for correct reading of the leveling rod, since the oscillations of the laser sight beam are symmetric with respect to its initial position.

To test the possibilities of using this rod, its prototype was produced. The method of precision leveling using the laser sighting device was tested during the installation and adjustment of the roller conveyor on the technical glass production line at the Saratovstroisteklo Company.

For experimental studies the prototype had the following modifications that are different from the theoretical design of the instrument: the laser sight was installed on the body of a N05 level, which allowed for the comparison between the traditional rod readings and the readings based on the laser beam projection on the rod (Fig. 3); the frame was manually moved along the rod, since the production of an optoelectron splitter involves certain expenses.

In the installation and adjustment of parallelism between the sight axis of the level (in readings based on the microme-

ter scale) and the laser beam, the distance between them was equal to 104.3 mm. This value was subsequently used to compensate for the difference between the heels in taking readings. Furthermore, instead of automatically installing the indication frame based on the laser beam spot, the readings were taken based on horizontal tangent lines above and beneath the spot. The final result was obtained as the mean of two readings, which were compared to the readings taken by the traditional method using the leveler crosshairs, taking into account the difference between the heels. In this particular case there was another deviation from the precise leveling procedure; the fractions of scale divisions were judged by eye. This was done to preserve the constant difference between the heels. Therefore, the standard rods with 5-mm scale divisions had to be replaced by rods with 1-mm divisions.

The experimental leveling was carried out on 103 conveyor rollers. At the same time, the effect of vibration on the precision of laser sight leveling was analyzed on 10 rollers near the main drive. The comparison of the results of traditional leveling with the results of laser sight leveling made it possible to assess the properties of the modified rods. It was found that the accuracy of directly reading the rod on a site without vibration was equal to 0.5 mm and on the site with vibration (within 30 μm) it was equal to 0.6 mm.

The obtained results in general were less accurate than required in precision leveling. However, it should be taken into account, first, that reading the rod in the traditional method initially involved an error, since the fractions of scale divisions were judged by eye and not with a micrometer (to preserve the difference between the heels), therefore, such data cannot be regarded as absolutely true values; second, that readings based on the laser beam spot estimating fractions of divisions above and beneath the spot did not meet the requirements of precision leveling either. Consequently, for an objective estimate the frame has to be automatically placed on the rod based on the indications of the optoelectron beam splitter. In this case the accuracy of readings grows by an order of magnitude. Considering other negative factors as well, such as the above mentioned beats of the rollers during rotation, the results of our studies are quite promising. Considering that the results of measurements obtained by both methods on the site with vibration are quite comparable, the proposed modifications can be used in the conditions where the traditional methods cannot ensure the required accuracy. It should be noted that under large amplitudes of the collimated ray oscillations it is impossible to read the leveling rod due to the blurring of the image in the telescope. At the same time, the oscillations of the laser beam (spot) with respect to the rod are registered by eye and, when using the beam splitter, altogether are of no great significance.

Thus, leveling with a laser beam in premises with poor visibility and intense vibrations perceptibly simplifies the measuring process, although the leveling accuracy is somewhat below the expected, approximately 1.5 – 2 times. Considering that the moving frame was set manually, it would be inappropriate to expect other results. Therefore, the frame should be automatically placed in the central position, since light diodes can estimate equal splitting of the light spot of the laser sight on the rod with a high accuracy even under intense vibration: the vibration of the beam or the rod is symmetric with respect to its initial position.